Complete Summary

GUIDELINE TITLE

Exercise testing for evaluation of hypoxemia and/or desaturation: 2001 revision and update.

BIBLIOGRAPHIC SOURCE(S)

Exercise testing for evaluation of hypoxemia and/or desaturation: 2001 Revision & Update. Respir Care 2001 May;46(5):514-22. [74 references]

GUIDELINE STATUS

This is the current release of the guideline.

This guideline updates a previously issued version (Exercise testing for evaluation of hypoxemia and/or desaturation. Respir Care 1992 Aug;37[8]:907-12).

COMPLETE SUMMARY CONTENT

SCOPE

DISEASE/CONDITION(S)

Pulmonary disease

GUIDELINE CATEGORY

Diagnosis
Evaluation

CLINICAL SPECIALTY

Family Practice
Internal Medicine
Pediatrics
Pulmonary Medicine

INTENDED USERS

Respiratory Care Practitioners

GUIDELINE OBJECTIVE(S)

- To improve the consistency and appropriateness of respiratory care and serve as a guide for education and research.
- To provide clinical practice guidelines on exercise testing for evaluation of hypoxemia and/or desaturation.

TARGET POPULATION

Pediatric, adolescent, adult, and geriatric patients with the following indications:

- The need to assess and quantify the adequacy of arterial oxyhemoglobin saturation during exercise in patients who are clinically suspected of desaturation (e.g., those who manifest dyspnea on exertion, decreased diffusing capacity of lung for carbon monoxide (DLCO), decreased partial pressure of arterial oxygen (P_{aO2}) at rest, or documented pulmonary disease)
- The need to quantitate the response to therapeutic intervention (e.g., oxygen prescription, medications, smoking cessation, or to reassess the need for continued supplemental oxygen)
- The need to titrate the optimal amount of supplemental oxygen to treat hypoxemia or desaturation during activity
- The need for preoperative assessment for lung resection or transplant
- The need to assess the degree of impairment for disability evaluation (e.g., pneumoconiosis, asbestosis)

This guideline does not apply to the neonatal population.

INTERVENTIONS AND PRACTICES CONSIDERED

Exercise testing for evaluation of hypoxemia and/or desaturation

MAJOR OUTCOMES CONSIDERED

Arterial blood gases and/or SpO2 should confirm or rule out oxygen desaturation during exercise to validate the patient's clinical condition.

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Not stated

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Systematic Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not applicable

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

External Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

Consultants to the Working Group may review the initial draft of the guideline. After completion by the Working group, the draft is reviewed by the entire Steering Committee and then by a Review Panel, persons engaged in all facets of the delivery of respiratory care who have volunteered to review drafts of the Guidelines before publication.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

Description/Definition:

Exercise testing may be performed to determine the degree of oxygen desaturation and/or hypoxemia that occurs on exertion. Desaturation is defined as a valid decrease in arterial oxygenation as measured by CO-oximetry saturation, (S_{aO2}) of 2% (based on the reproducibility of oxygenated hemoglobin (HbO_2) measurement at ±1%), an S_{aO2} <88%, and/or a blood gas partial pressure of arterial oxygen (PaO2) ≤55 torr.

- Exercise testing may also be performed to optimize titration of supplemental oxygen for the correction of hypoxemia. An S_{pO2} of 93% should be used as a target.
- It is preferable that this procedure be performed using a method that allows quantitation of workload and heart rate achieved (as % predicted).
    - This evaluation can be incorporated into other more complex test protocols (e.g., cardiac stress testing).
    - Continuous noninvasive measurement of arterial oxyhemoglobin saturation by pulse oximetry can provide qualitative information and an approximation of oxyhemoglobin saturation, with a 4% decrease in S_{pO2} considered significant, but evaluation of desaturation on exertion requires analysis of arterial blood samples drawn with the subject at rest and at peak exercise.
- Arterial blood specimens may be obtained by single puncture or by arterial cannulation.
- Exercise testing performed with exhaled gas analysis is addressed in a separate guideline.
- This guideline is appropriate for pediatric, adult, and geriatric patients who are capable of following test instructions and techniques.
    - The learning ability and communication skills of the patient being served should be taken into consideration when performing these tests.
    - The neonatal population is not served by this guideline.

Settings:

Exercise testing may be performed by trained personnel in a variety of settings including:

- Pulmonary function laboratories
- Cardiopulmonary exercise laboratories
- Clinics
- Pulmonary rehabilitation facilities
- Physicians' offices

Limitations of Procedure/Validation of Results:

- Limitations of equipment:

- Because of possible limitations of pulse oximetry with exercise and at rest, measurements may read falsely low or falsely high and should be validated by comparison with baseline arterial samples analyzed by CO-oximetry.
    - Only a limited number of pulse oximeters have been validated with results of concurrent arterial blood gas analysis in diseased subjects under exercise conditions.
    - Overestimation of oxygen saturation may occur with carboxyhemoglobin saturations (>4%).
    - Decreasing accuracy in S_{pO2} has been reported with desaturations to <83%. This is assumed to be the result of limitations of in vivo calibration to 85% with extrapolation of the calibration curve below that value.
    - Decreased perfusion with cardiovascular disease, vasoconstriction, or hypothermia may result in false-positive results or no valid data in some pulse oximeter models. Use of an alternative site should be evaluated (e.g., ear, finger, forehead). Alternative handwarming methods may be used to increase circulation.
    - Reduced ear perfusion associated with heavy exercise has been shown to affect S_{pO2} in some models of pulse oximeters.
    - Motion artifact may appear with exercise. Some pulse oximeters are better then others at rejecting motion artifact.
    - Pulse oximeter response time may be inadequate to describe rapid changes in saturation.
    - Skin pigmentation should, in theory, not affect pulse oximeter readings, but various studies report conflicting data depending on the manufacturer and model.
    - Hemoglobin disorders may affect the accuracy of the pulse oximeter reading. Important underestimation of arterial saturation may result from pulse oximetry in subjects with total hemoglobin levels of <= 8 g/dL.
    - Pulse oximetry is less useful over the range in which large changes in partial pressure arterial oxygen (P_{aO2}) are associated with small changes in arterial oxygenation as measured by CO-oximetry saturation (S_{aO2}) (i.e., $P_{aO2} \geq 60$ torr).
    - Ambient light during testing may interfere with measurements of pulse oximetry.
    - Exercise testing in which oxyhemoglobin saturation by pulse oximetry is the only variable measured provides limited information.
- Limitations related to the patient:
    - Additional limitations common to arterial sampling and analysis under resting conditions should be considered.
    - Patient cooperation level or physical condition may limit the subject's ability to exercise at a workload sufficient to evoke a response. Variables that are not adequately monitored (e.g., free walking) have limited application.
- Validation of results:
    - Arterial blood gas samples should be obtained at rest and at peak exercise. Samples from single arterial punctures have been shown to be equivalent to samples drawn from indwelling cannulas.

- In the unlikely event that a single puncture at peak exercise is unsuccessful in an uncannulated patient, a sample drawn within 10-15 seconds of the termination of exercise will suffice unless analysis shows a decrease from the resting values, in which case quantitation of desaturation requires a peak exercise sample obtained by cannula.
- Arterial blood gas results should be obtained according to the Guidelines for arterial blood gas sampling and for arterial blood gas analysis.
- Validity of pulse oximetry results is verified by comparison with the results of analysis by CO-oximetry, preferably at rest and at end of exercise.
    - S_{pO2} may be used to assess response to supplemental oxygen. If administration of supplemental oxygen does not improve a low S_{pO2}, arterial blood analysis may be warranted.
    - Testing should be performed in compliance with the American Association for Respiratory Care Pulse Oximetry Clinical Practice Guideline.
    - Correlation between pulse oximetry heart rate and palpated pulse rate and/or electrocardiogram should be established.
    - Pulse oximetry with pulse waveform display may be desirable. For patients with normal adult hemoglobin, the highest accuracy and best performance is attained when the probe is attached to the patient in such a way that the arterial signal has the largest possible amplitude, which is only available with systems that yield a plethysmographic tracing.

Assessment of Need:

Exercise testing for evaluation of hypoxemia and/or desaturation may be indicated in the presence of:

- a history and physical indicators suggesting hypoxemia and/or desaturation (e.g., dyspnea, pulmonary disease)
- abnormal diagnostic test results [e.g., diffusing capacity of lung for carbon monoxide ($D_{LCO,}$) forced expiratory volume in one second (FEV_1) resting arterial blood gases including directly measured oxygenated hemoglobin (HbO_2), oxygenated carbon monoxide (HbCO), and methemoglobin (HbMet)]
- the need to titrate or adjust a therapy (e.g., supplemental oxygen)

Assessment of Quality of Test and Validity of Results:

The consensus of the committee is that all diagnostic procedures should follow the quality model described in the NCCLS GP26-A A Quality System Model for Health Care (NCCLS, 940 West Valley Road, Ste. 1400, Wayne, PA 19087-1898; Web site: www.nccls.org). The document describes a laboratory path of workflow model that incorporates all the steps of the procedure. This process begins with patient assessment and the generation of a clinical indication for testing through the application of the test results to patient care. The quality system essentials defined for all health care services provide the framework for managing the path of workflow. A continuation of this model for respiratory care services is further described in NCCLS HS4-A A Quality System Model for Respiratory Care (NCCLS,

940 West Valley Road, Ste. 1400, Wayne, PA 19087-1898; Web site: www.nccls.org). In both quality models the patient is the central focus.

- General considerations include:
    - As part of any quality assurance program, indicators must be developed to monitor areas addressed in the path of workflow.
    - Each laboratory should standardize procedures and demonstrate intertechnologist reliability. Test results can be considered valid only if they are derived according to and conform to established laboratory quality control, quality assurance, and monitoring protocols.
    - Documentation of results, therapeutic intervention (or lack of) and/or clinical decisions based on the exercise testing should be placed in the patient's medical record. Report of test results should contain a statement by the technician performing the test regarding test quality (including patient understanding of directions and effort expended) and, if appropriate, which recommendations were not met.
    - The type of medications, dose, and time taken prior to testing and the results of the pretest assessment should be documented.
    - Test results should be interpreted by a physician, taking into consideration the clinical question to be answered.
    - A technologist who has not met annual competency requirements or whose competency is deemed unacceptable as documented in an occurrence report should not be allowed to participate, until he has received remedial instruction and has been re-evaluated.
    - There must be evidence of active review of quality control, proficiency testing, and physician alert, or 'panic' values, on a level commensurate with the number of tests performed.
- Calibration and quality control measures specific to equipment used in exercise testing for desaturation include:
    - Calibration procedures as defined by the laboratory protocols and manufacturer's specifications should be adhered to.
    - Treadmills and bicycle ergometers should be calibrated according to the manufacturer's recommendations, with periodic re-verification. (One reference suggests every 3-6 months.)
    - Pulse oximeters monitors should be maintained as described under quality assurance in the manufacturer's manual.
    - Biological controls should be tested regularly (self-testing of normal laboratory staff).
- Test quality: Results of arterial blood gas analysis and/or S_{pO2} should confirm or rule out oxygen desaturation during exercise to validate the patient's clinical condition.
- Test results: The exercise should have a symptom-limited or physiologic end point documented (e.g., heart rate or onset of dyspnea).

Resources:

- Equipment:
    - Treadmill, cycle ergometer, or equivalent equipment, adaptable to patients who may be severely limited (e.g., low-speed treadmill, low-watt ergometer, arm crank ergometer). Other forms of exercise may be utilized (stair climbing, step test, timed walking); however, such modes do not eliminate the necessity for adequate monitoring and the

necessity for adequate documentation of procedure and patient response.
    - Arterial blood sampling equipment for single puncture or arterial cannulation and analyzers that have been properly calibrated and for which multilevel controls indicate proper function
    - Pulse oximeter monitor and related accessories.
    - Electrocardiographic monitor with the capacity to monitor heart rate to a predicted maximum and accurately display cardiac rhythm during exercise. (Multiple leads are preferred.)
    - Resuscitation equipment including oxygen with various delivery devices, such as nasal cannula and mask.
    - An easily accessible cardiac arrest cart and defibrillator with resuscitation equipment
    - Blood pressure monitoring device, manual or automatic. (If an automated system is used, a manual blood pressure cuff and stethoscope should be available as a backup.)
    - Visual aids (e.g., Borg scales for dyspnea and fatigue) that are large, easy to read, and in clear view.
    - Blood gas sampling and analysis equipment.
- Background history and data:
    - Results of appropriate baseline diagnostic tests and patient history (e.g., electrocardiogram, chest radiograph, and pulmonary function test results) should be available.
    - The need for written consent should be determined within the specific institution.
    - A list of the patient's current medications and any pharmacologic allergies should be included.
- Personnel:
    - The presence of a physician trained in exercise testing may be required depending on patient condition and hospital policy.
    - Personnel administering the test should possess experience and knowledge in exercise physiology and testing, including arterial blood gas sampling and analysis; cardiopulmonary resuscitation (certified in Basic Cardiac Life Support, or BCLS. Qualification in Advanced Cardiac Life Support, or ACLS, is recommended); electrocardiograph abnormality recognition; oxygen therapy; blood pressure monitoring; and application and limitations of pulse oximeters. Training and demonstrated competency must be documented for all testing personnel.
        - Testing personnel should have the knowledge and skills to respond to adverse situations with the patient and to know when cessation of further testing is indicated (versus coaching the patient to continue).

Monitoring:

- Recommended monitoring of patient during testing:
    - Electrocardiograph with strip recorder, preferably screened in real-time to check for displaced leads
    - Oxygen delivery devices with documented FDO_2
    - Physical assessment (chest pain, leg cramps, color, perceived exertion, dyspnea)

- Respiratory rate
- Patient cooperation and effort level
- Borg, modified Borg, or visual analog dyspnea or symptom scales
- Blood gas sampling using site and technique consistent with the American Association for Respiratory Care clinical practice guidelines for blood gas sampling, and NCCLS guidelines (NCCLS, 940 West Valley Road, Ste. 1400, Wayne, PA 19087-1898; Web site: www.nccls.org)
- Continuous monitoring of oxygenation status (S_{pO2})
- Heart rate, rhythm, and ST-T wave changes
- Blood pressure

- Recommended equipment monitoring during testing: Pulse waveforms of S_{pO2} and/or arterial oxygenation as measured by CO-oximetry saturation (S_{aO2}) should be analyzed to assure adequate signal acquisition for reliable readings.

Frequency:

The frequency of testing depends on the patient's clinical condition and the need for changes in therapy. Exercise may be repeated for certification of supplemental oxygen needs.

Infection Control:

- The staff, supervisors, and physician-directors associated with the pulmonary laboratory should be conversant with the "Guideline for Isolation Precautions in Hospitals" made by the Centers for Disease Control and Prevention and the Hospital Infection Control Practices Advisory Committee (HICPAC), and develop and implement policies and procedures for the laboratory that comply with its recommendations for "Standard Precautions" and "Transmission-Based Precautions."
- The laboratory's manager and its medical director should maintain communication and cooperation with the institution's infection control service and the personnel health service to help assure consistency and thoroughness in complying with the institution's policies related to immunizations, post-exposure prophylaxis, and job- and community-related illnesses and exposures.
- Primary considerations include:
  - adequate handwashing
  - provision of prescribed ventilation with adequate air exchanges
  - careful handling and thorough cleaning and processing of equipment

    Procedure-specific considerations include:

    - disposable items are for single patient use
    - disposable electrodes should be used for electrocardiographic monitoring with Standard Precautions observed during patient skin preparation. Cables and equipment that touch the patient should be wiped down with a disinfectant after each use
    - reusable pulse oximeter probes should be cleaned between patient use, following the manufacturer's guidelines
  - the exercise of particular care in scheduling and interfacing with the patient in whom a diagnosis has not been established

Age Specific Issues

- This guideline does not apply to the neonatal population.
- This clinical practice guideline document applies to pediatric, adolescent, adult, and geriatric populations.
- Test instructions and techniques should be given in a manner that takes into consideration the learning ability, communication skills, and age of the patient being served.

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

Not specifically stated for each recommendation.

The guideline is developed from a thorough review of the literature, surveys of current practice, and the expertise of the members of the Working Group.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

Appropriate use of exercise testing for evaluation of hypoxemia and/or desaturation.

POTENTIAL HARMS

- Indications for immediate termination of testing include:
    1. electrocardiographic abnormalities (e.g., dangerous dysrhythmias, ventricular tachycardia, ST-T wave changes)
    2. severe desaturation as indicated by an arterial oxygenation as measured by CO-oximetry saturation (S_{aO2}) $\leq$80% or S_{pO2} $\leq$83% (a number of pulse oximeters have been found to overestimate S_{pO2}) and/or a 10% fall from baseline values; (Underestimation of saturation has been noted to occur with certain pulse oximeter models.)
    3. angina
    4. hypotensive responses:
        - a fall of greater than 20 torr in systolic pressure, occurring after the normal exercise rise
        - a fall in systolic blood pressure below the pre-exercise level
    5. lightheadedness
    6. request from patient to terminate test
- Abnormal responses that may require discontinuation of exercise include:
    1. a rise in systolic blood pressure to greater than 50 torr or of diastolic pressure to greater than 120 torr, or a rise in systolic pressure of less than 20 torr from resting level

2. mental confusion or headache
3. cyanosis
4. nausea or vomiting
5. muscle cramping

- Hazards associated with arterial puncture, arterial cannulation, and pulse oximetry. Pulse oximetry is a noninvasive safe procedure, but because of device limitations, false-negative results for hypoxemia and/or false-positive results for normoxemia or hyperoxemia may lead to inappropriate treatment of the patient. Although it is rare, tissue injury may occur at the measuring site as a result of probe misuse, such as pressure sores from prolonged application or electrical shock and burns from the substitution of incompatible probes between instruments.

CONTRAINDICATIONS

CONTRAINDICATIONS

- Absolute contraindications include:
  1. acute electrocardiographic changes suggesting myocardial ischemia or serious cardiac dysrhythmias including bradydysrhythmias, tachydysrhythmias, sick sinus syndrome, and multifocal premature ventricular contractions (PVCs), causing symptoms of hemodynamic compromise (occasional premature ventricular contractions are not a contraindication)
  2. unstable angina
  3. recent myocardial infarction (within the previous 4 weeks) or myocarditis
  4. aneurysm of the heart or aorta
  5. uncontrolled systemic hypertension
  6. acute thrombophlebitis or deep venous thrombosis
  7. second- or third-degree heart block
  8. recent systemic or pulmonary embolus
  9. acute pericarditis
  10. symptomatic severe aortic stenosis
  11. uncontrolled heart failure
  12. uncontrolled or untreated asthma
  13. pulmonary edema
  14. respiratory failure
  15. acute non-cardiopulmonary disorders affected by exercise
- Relative contraindications include:
  1. situations in which pulse oximetry may provide invalid data (e.g., elevated oxygenated carbon monoxide (HbCO), methemoglobin (HbMet), or decreased perfusion). (See the AARC Pulse Oximetry Guidelines)
  2. situations in which arterial puncture and/or arterial cannulation may be contraindicated
  3. a non-compliant patient or one who is not capable of performing the test because of weakness, pain, fever, dyspnea, incoordination, or psychosis
  4. severe pulmonary hypertension (cor pulmonale)
  5. known electrolyte disturbances (hypokalemia, hypomagnesemia)

6. resting diastolic blood pressure greater than 110 torr or resting systolic blood pressure greater than 200 torr
7. neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
8. uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema
9. S_{aO2} or S_{pO2} less than 85% on room air
10. complicated or advanced pregnancy
11. hypertrophic cardiomyopathy or other forms of outflow tract obstruction
12. patient's inability to cooperate or follow directions for testing

QUALIFYING STATEMENTS

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Test instructions and techniques should be given in a manner that takes into consideration the learning ability, communication skills, and age of the patient being served.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Getting Better
Living with Illness

IOM DOMAIN

Effectiveness
Safety

IDENTIFYING INFORMATION AND AVAILABILITY

BIBLIOGRAPHIC SOURCE(S)

Exercise testing for evaluation of hypoxemia and/or desaturation: 2001 Revision & Update. Respir Care 2001 May;46(5):514-22. [74 references]

ADAPTATION

Not applicable: The guideline was not adapted from another source.

DATE RELEASED

2001 May

GUIDELINE DEVELOPER(S)

American Association for Respiratory Care - Professional Association

SOURCE(S) OF FUNDING

American Association for Respiratory Care (AARC)

GUIDELINE COMMITTEE

Cardiopulmonary Diagnostics Guidelines Committee

COMPOSITION OF GROUP THAT AUTHORED THE GUIDELINE

Committee Members: Catherine M Foss BS, RRT, RPFT; Susan Blonshine BS, RRT, RPFT; Carl Mottram BA, RRT, RPFT, Chair; Gregg Ruppel Med, RRT, RPFT; Jack Wanger MS, RRT, RPFT

FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

Not stated

GUIDELINE STATUS

This is the current release of the guideline.

This guideline updates a previously issued version (Exercise testing for evaluation of hypoxemia and/or desaturation. Respir Care 1992 Aug;37[8]:907-12).

GUIDELINE AVAILABILITY

Electronic copies: Available from the American Association for Respiratory Care (AARC) Web site.

Print copies: Available from AARC, CPG Desk, 11030 Ables Ln, Dallas, TX 75229-4593.

AVAILABILITY OF COMPANION DOCUMENTS

None available

PATIENT RESOURCES

None available

NGC STATUS

This summary was completed by ECRI on November 30, 1998. The information was verified by the guideline developer on December 15, 1998. This summary was updated by ECRI on August 24, 2001. The updated information was verified by the guideline developer as of October 17, 2001.

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